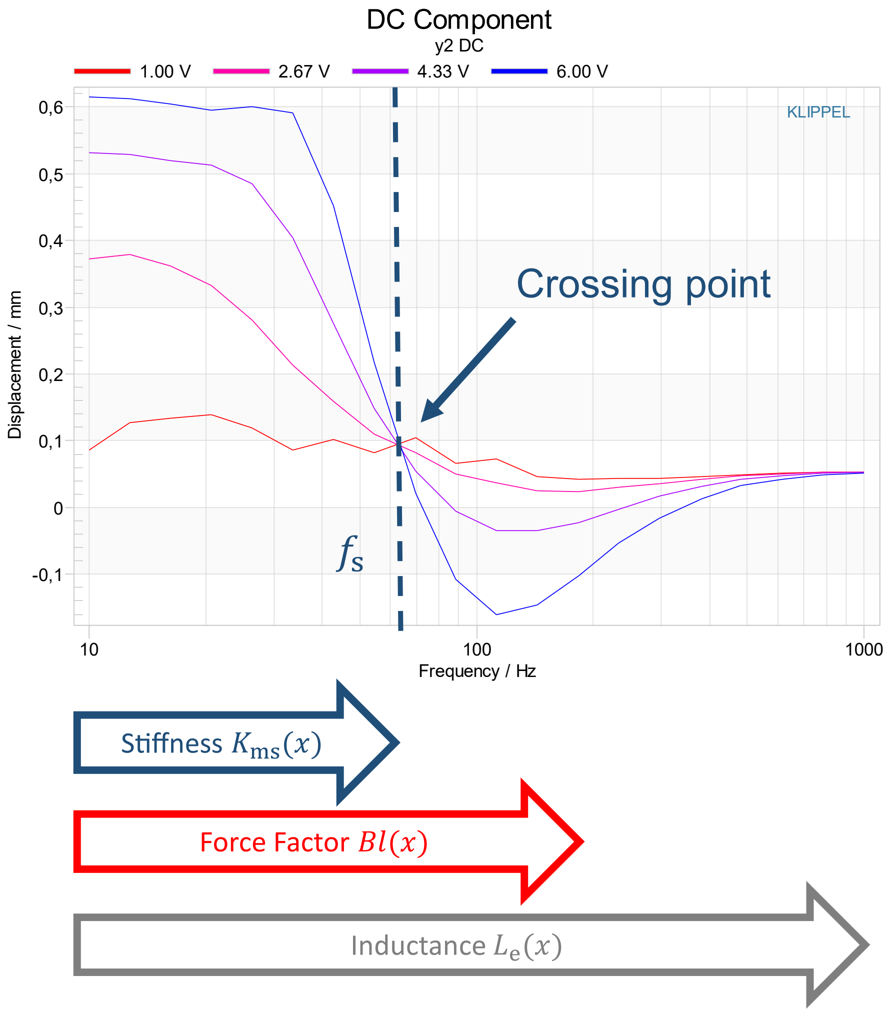
Dynamic Generation of DC Displacement AN13

Application Note to the KLIPPEL R&D system (Document Revision 1.2)

DESCRIPTION

Nonlinearities inherent in the transducer produce a DC component in the voice coil displacement by rectifying the AC signal. Magnitude and direction of the dynamically generated DC component depend on the type of nonlinearity and on the frequency and voltage of the excitation signal. The 3D Distortion (DIS) module is used to measure the DC component versus voltage and frequency. The results reveal the stability of the driver, the cause of distortion and complicated interaction between driver nonlinearities.



CONTENTS:

1 Physics of generating DC-displacement

Causes

There are two mechanisms that generate a DC component in the displacement:

1. Any asymmetry in the nonlinear characteristics of the electrical and mechanical parameters partially rectifies the AC signal. This generates a DC component along with second-order and higher-order distortions. When the transducer is excited by a complex signal, the DC component has a much higher amplitude than any other harmonic or intermodulation component. This occurs because the DC component is accumulated by rectifying any fundamental component whereas the other distortion components are distributed over the whole frequency band.
2. An electrodynamic motor with a perfectly symmetrical $Bl(x)$ characteristic may become unstable if the suspension stiffness is very low and the driver is operated above the resonance frequency. Any small DC force caused by motor asymmetries or an external disturbance (e.g. a fingertip) will generate a DC displacement moving the coil down the slope of $Bl(x)$ until the restoring force of the suspension will stop this process.

Orientation

The sign of the DC displacement determines the direction of the voice coil shift. In this application note positive displacements x denotes shifts that the coil moves away from the backplate (coil out).

Direction

The direction of the DC displacement depends on the shape (extrema, asymmetry) of the transducer nonlinearities and the frequency of the excitation tone:

- The DC displacement caused by an asymmetric stiffness $K_{ms}(x)$ moves the coil always towards the direction of the stiffness minimum. A significant DC displacement at resonance is the unique symptom for the $K_{ms}(x)$ nonlinearity.
- The DC component produced by the force factor $Bl(x)$ depends on the frequency of the fundamental component. For frequencies below the resonance frequency the coil is moved towards the maximum of the $Bl(x)$ curve. This means that the coil is self-centering, which is a nice feature. Unfortunately, the same motor will push the coil away from the $Bl(x)$ maximum for any frequency above the resonance.
- An asymmetric inductance $L_e(x)$ causes a small DC component that moves the coil towards higher inductance values, similar to the attraction force in an electromagnet.

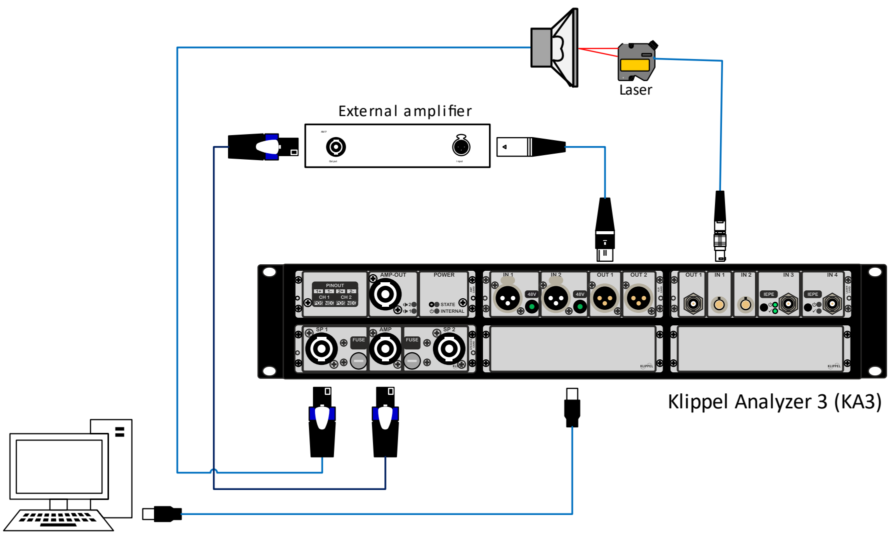
Nonlinearity	Frequency of the Excitation Tone			
	$f < f_s$	$f = f_s$	$f > f_s$	$f \gg f_s$
$Bl(x)$ (motor)	Moves coil to $Bl(x)$ maximum	No DC component	Moves coil away $Bl(x)$ maximum	Negligible
$K_{ms}(x)$ (Suspension)	Moves coil to $K_{ms}(x)$ minimum	Moves coil to $K_{ms}(x)$ minimum	Negligible	Negligible
$L_e(x)$ (Reluctance force)	Moves coil to $L_e(x)$ maximum	Negligible	Moves coil to $L_e(x)$ maximum	Moves coil to $L_e(x)$ maximum

Crossing point

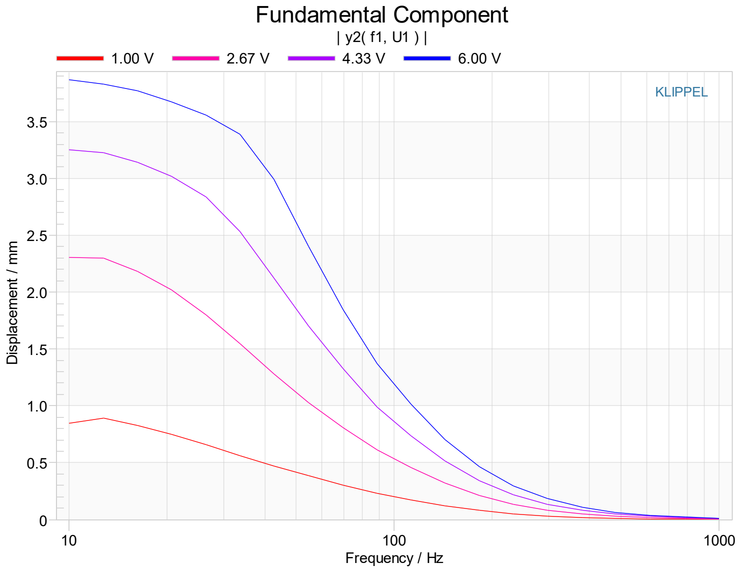
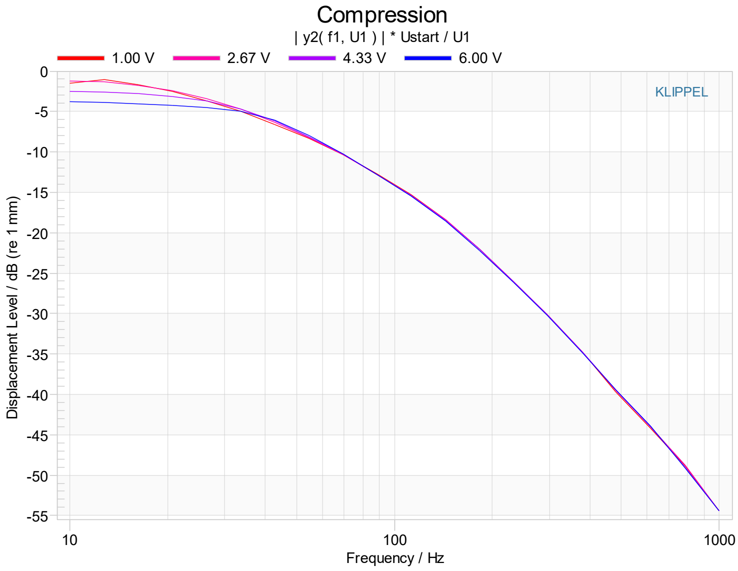
Some loudspeakers produce both positive and negative DC displacement depending on the frequency of the excitation tone. At the point where positive displacement begins to change to negative and vice versa (crossing point) all the DC forces produced by the different rectification processes cancel out each other. This point is quite reproducible and almost independent of the magnitude of the DC component.

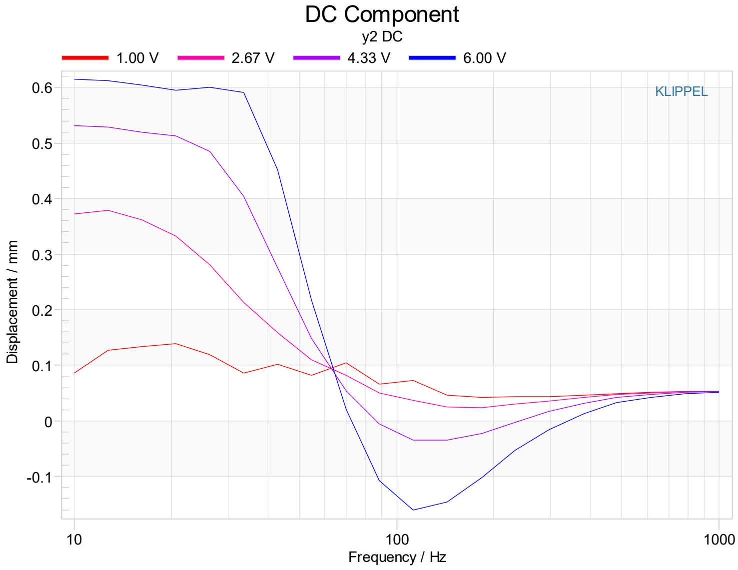
Influence of the suspension creep	The DC displacement of real-world transducers varies with active operation. After starting to operate the transducer an initial DC component is generated. The magnitude of DC displacement depends among others on the stiffness of the suspension at very low frequencies ($f \approx 0$ Hz). However, the stiffness of the suspension of real transducers is frequency dependent. Usually, the suspension is much stiffer at the resonance frequency than at very low frequencies (corresponding to very slow cone movements). Any displacement of the suspension will cause changes in the geometry of the fibers of the rubber and fabric, and the relocation time has a time constant in the order of magnitude of 1s. The loss of stiffness at lower frequencies is described by the creep factor which can be measured with Linear Parameter Measurement (LPM) module of the Klippel Analyzer System. The DC force will produce a variable DC displacement depending on the creep factor and the measurement time.

2 Using the KLIPPEL R&D System

Requirements	• Klippel Analyzer (KA3 or DA2) + PC • Laser sensor • dB-Lab Software • 3D Distortion (DIS) software module
Setup	• Connect external power amplifier or use internal AMP-Card of KA3 • Mount DUT to the driver stand and connect terminals with speaker output of Klippel Analyzer • Connect laser with laser input of Klippel Analyzer and adjust beam to diaphragm of the speaker. Note: A dot of white ink shall be used to increase the signal to noise ratio of the measured displacement signal 
Preparation	Create new object based on the object template “DIS X fundamental, DC AN13” provided in the dB-Lab object templates.
DIS measurement	1. Start measurement 2. Open windows “Fundamental” and “DC Component”. If the voltage U_{end} is too low for the particular driver, adjust U_{end} in property page “Stimulus” and repeat the measurement 3. Check the results or create a report

3 Example

Fundamental displacement and compression	The result window "Fundamental" displays the rms displacement versus frequency f_1 and amplitude U_1.  Due to the linear spacing of the input voltage the amplitude responses are equally spaced in the small signal domain. At low frequencies there is an amplitude compression at high signal amplitudes due to the nonlinear mechanism. 
DC component	The result window "DC Component" shows the DC Displacement versus voltage U_1 and frequency f_1. The speaker in the example produces both positive and negative DC components depending on the frequency of the excitation tone. The crossing point at about f = 60 Hz close to the resonance frequency of the loudspeaker. These are typical characteristics for a motor with asymmetric *Bl*(*x*) and nonlinear suspension. Shifting the rest position of the coil to positive displacement (out) would increase the *Bl*(*x*=0) value and improve the stability of the driver. For more information, please refer to the paper [Loudspeaker Nonlinearities – Causes, Parameters, Symptoms].

4 More Information

Application Notes	Motor Stability, Application Note AN 14
Related Specification	3D Distortion Measurement (DIS), Specification DIS Linear Parameter Measurement (LPM), Specification LPM Klippel Analyzer 3 (KA3), Specification H3 Laser displacement sensor, Specification A2
Manuals	User Manual 3D Distortion Measurement
Paper	W. Klippel, “Loudspeaker Nonlinearities – Causes, Parameters, Symptoms”, presented at the 119th Convention of the Audio Engineering Society, 2006 October 6-8, San Francisco, USA

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html

Last updated: 23.01.2026